

**Post-Hooking Mortality in Pelagic Longline Fisheries Using “J” Hooks and Circle Hooks**  
**Application of New Draft Criteria to Data from the Northeast Distant Experiments**  
**in the Atlantic**

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Herein we provide estimates of post-hooking mortality ratios for loggerhead and leatherback sea turtles captured on pelagic longlines targeting swordfish. We provide estimates for the mortality associated with circle hooks and for “J” hooks. The draft criteria were developed at a post-hooking mortality workshop in Bethesda, Maryland January 15-16, 2004. These criteria categorize mortality based on the location of the wound, if hooked, the amount of line remaining on the turtle when released, and whether the hook was removed. These draft criteria were provided in a January 22, 2004 memo from Laurie K. Allen, Director of the Office of Protected Resources, to Samuel G. Pooley, Acting Director of NMFS Pacific Islands Regional Office, and to Jeffrey Polovina, Acting Director of the NMFS Pacific Islands Science Center (Table 1).

These criteria were applied to data collected during pelagic experiments conducted 2002-2003 in the Northeast Distant (NED) statistical reporting area of the North Atlantic Ocean. The purpose of these experiments was to modify gear and or fishing practices to effect a reduction in sea turtle bycatch. Those results indicate that the use of circle hooks significantly reduces sea turtle bycatch by as much as 86% (90% when baited with mackerel) when compared to the industry standard “J” hooks baited with squid (Watson et al., 2003a). These animals should represent the frequency of entanglement and distribution and hooking events in various body locations on leatherback and loggerhead sea turtles.

Hook type does make a difference in the hook’s location on the turtle (Watson et al., 2003a). We did not also categorize the data separately by bait type for several reasons. The evidence that bait type makes a difference in hooking location was weak, partly because examination of bait effects within hook types greatly reduces already small sample sizes. Moreover, management measures under consideration in the Atlantic and Pacific allow greater flexibility in bait type than in hook type, so we thought it prudent to retain the effects of all bait types in the summary estimates. Similarly, we did not categorize the data separately by hook offset. Again, the evidence that offset (up to 10 degrees) makes a difference in hooking location was weak for the same reason given above for bait type. Lastly, we combined data from 18/0 (used in 2002 and 2003) and 20/0 circle hooks (used only in 2003) for the analysis. We excluded the smaller 16/0 circle hooks (used only in 2003) since there is some evidence that, in general, smaller hooks may be more easily ingested by loggerheads (Watson et al., 2003b) and because current draft proposed rules do not allow the use of these smaller hooks.

Detailed data were collected on all turtles captured, including hook location, whether it was removed or not, and the amount of any line remaining on the turtle. This database is maintained by the Sea Turtle Team of the Southeast Fisheries Science Center. The 2002-2003 data were sorted into the 6 post-hooking mortality categories and then further binned according to amount of gear removed.

**Category I** was defined as the hook recorded in any of the following locations:

```
if hooked_where_ eq '9' /* front flipper/shoulder/armpit */  
  or hooked_where_ eq '10' /* rear flipper/groin/tail */  
  or hooked_where_ eq '3' /* flipper */  
  or hooked_where_ eq '4' /* carapace/plastron */  
  or hooked_where_ eq '5' /* beak/head/neck(external) */  
  or hooked_where_ eq 'a' /* armpit */  
  or hooked_where_ eq 'b' /* beak(internal) */  
  or hooked_where_ eq 'k' /* beak(external) */  
  or hooked_where_ eq 'l' /* tail */
```

```

or hooked_where_ eq 'c' /* carapace */
or hooked_where_ eq 'f' /* front flipper */
or hooked_where_ eq 'g' /* groin */
or hooked_where_ eq 'h' /* head */
or hooked_where_ eq 'n' /* neck */
or hooked_where_ eq 'p' /* plastron */
or hooked_where_ eq 'r' /* rear flipper' */
or hooked_where_ eq 's' /* shoulder */
or hooked_where_ eq 'ue' /* unknown external */

```

Note that we have categorized beak-hooked animals here. The draft criteria are silent on their placement. We made the decision to place these animals in Category I because (1) the rhamphotheca (beak) is both external and internal; (2) the rhamphotheca are keratinous beaks and are hard, and in most Cheloniid species (exception is green turtles) are moderately to heavily constructed (Wyneken, 2001). Hooks generally only lightly penetrate it. The observers generally report that these hooks require little effort to remove. Removal is most often done by hand, and with little or no bleeding (NMFS unpublished data); (3) the rhamphotheca is at best minimally innervated and vascularized, although the underlying tissue between the rhamphotheca and the bone is innervated and moderately vascular (Wyneken, 2001; personal communication; Harms, personal communication); and (4) post-workshop communications from participants Dr. Jeanette Wyneken, Dr. Craig Harms, and Dr. Thierry have recommended that beak-hooked turtles be placed in the category with externally hooked turtles (Category I), while Dr. Joe Flanagan opined that they should be placed in the category for the lower jaw (Category II). Furthermore, placement of beak hooked turtles with externally hooked turtles is consistent with the former (2001) post-hooking mortality criteria (sic “lip-hooked”). Note that *Dermochelys* do not have rhamphotheca and thus, never would be coded as beak-hooked.

**Category II** was defined as the hook recorded in any of the following locations:

```

if hooked_where_ eq 'm' /* mouth */ and jaw_location eq 'l' /* lower jaw */

```

The draft criteria are silent about hooks in the side/corner of the mouth/jaw, except to indicate that animals hooked in the jaw joint should be placed in Category III below. Hooking in the side/corner of the mouth happens frequently in loggerheads, but it is a location where hooks can be removed easily. Usually the barb or eye of the hook is cut away and then the hooked backed out without further damage. Generally, we believe that animals hooked in the corner of the mouth should be placed in this category. Furthermore, in post-workshop communications with Dr. Jeanette Wyneken, Dr. Craig Harms, and Dr. Joe Flanagan, these participants recommended that hooking events in the side/corner of the mouth/jaw, not involving the jaw joint, be placed herein (with lower jaw, Category II). In contrast, Dr. Thierry Work recommended that animals hooked in the corner of the mouth/side of jaw be placed in Category III. Since it was not noted whether the jaw joint was involved on the data sheets, for this exercise we placed all animals hooked in the corner of the mouth in Category III, assuming the worst (jaw joint involvement).

**Category III** was defined as hook recorded in any of the following locations:

```

if hooked_where_ eq '2' /* beak/mouth/tongue/glottis */
or hooked_where_ eq 'm' /* mouth */ and jaw_location ne 'l' /* not lower jaw */
or hooked_where_ eq 'o' /* glottis */
or hooked_where_ eq 't' /* tongue */
or ((hooked_where_ eq 'i' or hooked_where_ eq 'w' /* swallowed */) and
line_left eq 0) /* cervical esophageal hook if all line can be removed */

```

The draft criteria distinguish between hooks in the cervical esophagus and those at the level of the heart or lower. We used amount of line left as the distinguishing factor for swallowed hooks. If all line was removed, then the eye of the hook was accessible and thus the hook was in the cervical esophagus. If all line was not removed then we assumed that the eye of the hook was not accessible and those animals were placed into Category IV below.

**Category IV** was defined as hook recorded in any of the following locations:

```
if hooked_where_ eq 'll' /* not known if hooked */  
  or hooked_where_ eq 'u' /* unknown location */  
  or hooked_where_ eq 'ui' /* unknown internal */  
  or ((hooked_where_ eq 'i' or hooked_where_ eq 'w' /* swallowed */) and  
      line_left gt 0) /* hook is in esophagus at or below level of heart  
                      if all line cannot be removed */
```

Note that all turtles for which the hook location was unknown were placed in this category, the most severe (highest mortality) observed for loggerheads. In contrast, the most severe category observed for leatherbacks was mouth hooks (Category III). For each set of data, circle hooks and “J” hooks, there were 3 leatherbacks that were not known if hooked or the hooking location was unknown. In 2 cases in each dataset, all gear had been retrieved and in the 3<sup>rd</sup> case most gear had been retrieved (remaining line was less than ½ carapace length). Thus, we placed all leatherbacks with hooks in unknown locations in Category III, the most severe category observed for this species..

**Category V** was defined as animals not hooked:

```
else if hooked_where_ eq '7' /* not hooked */
```

This was the most elusive category to quantify. Turtles are sometimes entangled in the main line or float lines. When several types of hooks are deployed on the same set the hook type for such turtles is unknown unless entanglement (without hooking) is on a branch line (each branch line has a known hook type). We could have assumed that entanglement rates are independent of hook type. However, it is likely that entanglement (not hooked) rates vary if certain hook types alter the likelihood that the turtle will be hooked. We used a proxy to estimate the number of animals that were only entangled.

To estimate the proportion of animals entangled on fishing gear deployed with only circle hooks, we examined only the 2003 data representing mackerel bait sets. Only circle hooks were set with mackerel during 2003, except for brief period during the early season when Japanese tuna hooks were used, also. Fortunately no turtles were caught on the tuna hooks, so we assumed that all turtles not hooked in 2003 mackerel sets were entangled on gear deployed with circle hooks. The proportion of turtles that were only entangled was determined from this data subset (13 out of 39 leatherbacks, 1 out of 12 loggerheads) and then an estimate of the total number of turtles entangled for all circle hooks during 2002-2003 was calculated in proportion to the number hooked.

A similar exercise was done to estimate the proportion of animals entangled only on gear set with “J” hooks by using 2001 experiment data. Only “J” hooks were set in 2001, when 13 out of 77 leatherbacks, and 2 out of 142 loggerheads were not hooked (entangled only).

There were no comatose and resuscitated turtles in the sample (**Category VI**).

These categories were further subdivided based on the amount of gear removed:

### **Column 3**

```
if (hook_removed_eq 1 /*yes*/ or hook_removed_eq 3 /* NA */)
  and line_left eq 0 /* all gear removed */ /* column 3 */
```

### **Column 2**

```
if line_left lt 0.5*CL_est /* column 2 */
```

### **Column 1**

```
if line_left ge 0.5*CL_est /* column 1 */
```

These were applied to all Categories except Category 5, the animals that were only entangled. It was assumed that for the entangled turtles gear removal success was not dependent on the type of hook being employed. We used the 2002-2003 data on animals not hooked to determine the success of removing gear from turtles that were only entangled (95% for leatherbacks and 100% for loggerheads) and applied that distribution to our estimated number of animals only entangled for each hook type.

Lastly, we applied each cell's (category x column) mortality estimate (Table 1), by species, to the frequency of individuals in each cell and determined the overall mortality ratio for each species group (Tables 2 and 3). We also applied the older NMFS post-hooking mortality criteria (February 2001) for comparison.

For "J" hooks those mortality ratios are 0.138 for leatherbacks and 0.330 for loggerheads (which is assumed representative for all hardshell turtles). In comparison, using the older mortality criteria, these ratios were 0.223 and 0.294, respectively.

For circle hooks, those mortality ratios are 0.131 for leatherbacks and 0.170 for loggerheads. In comparison, using the older mortality criteria, these ratios were 0.204 and 0.344, respectively.

Circle hooks do reduce the bycatch of leatherbacks (Watson et al., 2003a) but they do not greatly alter the mortality of those that are caught.

Conversely, not only do circle hooks significantly reduce the bycatch of loggerhead turtles but the mortality rate of turtles that are caught on circle hooks is about half that of animals caught on "J" hooks. This is because a much higher proportion of "J" hooks were swallowed. Circle hooks most often catch in the mouth where the resulting mortality appears to be less and where the gear is accessible to be removed.

Table 1. Criteria for assessing marine turtle post-interaction mortality after release from longline gear. Percentages are shown for hardshelled turtles, followed by percentages for leatherbacks (in parentheses). Draft from January 22, 2004 memo from Laurie Allen.

Nature of Interaction		Released with hook and with line greater than or equal to half the length of the carapace	Release with hook and with line less than half the length of the carapace	Released with all gear removed
Category		Hardshell (Leatherback)	Hardshell (Leatherback)	Hardshell (Leatherback)
I	Hooked externally with or without entanglement	20 (30)	10 (15)	5 (10)
II	Hooked in lower jaw (not adnexa <sup>1</sup> ) with or without entanglement	30 (40)	20 (30)	10 (15)
III	Hooked in cervical esophagus, glottis, jaw joint, soft palate, or adnexa (and the insertion point of the hook is visible when viewed through the mouth) with or without entanglement	45 (55)	35 (45)	25 (35)
IV	Hooked in esophagus at or below level of the heart (includes all hooks where the insertion point of the hook is not visible when viewed through the mouth) with or without entanglement	60 (70)	50 (60)	n/a <sup>2</sup>
V	Entangled Only	Released Entangled 50 (60)		Fully Disentangled 1 (2)
VI	Comatose/resuscitated	n/a <sup>3</sup>	70 (80)	60 (70)

<sup>1</sup> Subordinate part such as tongue, extraembryonic membranes

<sup>2</sup> Per veterinary recommendation hooks would not be removed if the insertion point of the hook is not visible when viewed through the open mouth.

<sup>3</sup> Assumes that a resuscitated turtle will always have the line cut to a length less than half the length of the carapace, even if the hook cannot be removed.

Table 2. Turtles caught on swordfish-style gear using 9/0 “J” hooks by NED research fleet in 2002-2003.

Species	Total	Released Alive														Dead	
		Hooked with or without entanglement										V. Entangled		VI. Comatose			
		I. Externally			II. Lower jaw			III. Upper mouth/throat			IV. Deep esoph.		only*		and resuscitated		
		Hook & line >.5 cp. len.	Hook & line <.5 cp. len.	All gear re-moved	Hook & line >.5 cp. len.	Hook & line <.5 cp. len.	All gear re-moved	Hook & line >.5 cp. len.	Hook & line <.5 cp. len.	All gear re-moved	Hook & line >.5 cp. len.	Hook & line <.5 cp. len.	releas-ed en-tangled	disen-tangled	Hook & line <.5 cp. len.		All gear re-moved
Leatherback	147	22	30	60	0	1	0	0	1	2	0	0	2	29	0	0	0
Loggerhead	131	0	0	17	0	0	2	0	36	30	0	44	0	2	0	0	0
All species	278	22	30	77	0	1	2	0	37	32	0	44	2	31	0	0	0

Mortality ratio:

Hardshells	0.20	0.10	0.05	0.30	0.20	0.10	0.45	0.35	0.25	0.60	0.50	0.50	0.01	0.70	0.60	1.00
Leatherbacks	0.30	0.15	0.10	0.40	0.30	0.15	0.55	0.45	0.35	0.70	0.60	0.60	0.02	0.80	0.70	1.00

Overall Ratio:		Calculated mortality for each cell in the matrix (no. turtles times mortality ratio)															
Leatherback	0.138	6.6	4.5	6	0	0.3	0	0	0.45	0.7	0	0	1.2	0.58	0	0	0
Hardshell**	0.330	0	0	0.85	0	0	0.2	0	12.6	7.5	0	22	0	0.02	0	0	0
All species	0.228	6.6	4.5	6.85	0	0.3	0.2	0	13.05	8.2	0	22	1.2	0.6	0	0	0

\*Estimates of the ratio of entangled only to total takes were obtained from a subsample of sets where all turtles were caught on J hooks.

This ratio was used to estimate entangled only takes from the hooked takes on J hooks from 2002-2003. The ratio of released entangled leatherbacks to total entangled leatherbacks was 0.05 for all hook types in 2002-2003. This ratio was used to estimate the number of released entangled leatherbacks. No loggerheads were ever released entangled. All other numbers of turtles by categories are totals from the NED observer data as summarized by Epperly (SEFSC).

\*\*All hardshell turtles assumed to have a mortality ratio like loggerheads, since there were too few NED data on other spp to make direct estimates for olive ridley or green turtles

Table 3. Turtles caught on swordfish-style gear using 18/0 circle hooks by NED research fleet in 2002-2003.

Species	Total	Released Alive														Dead	
		Hooked with or without entanglement										V. Entangled only*		VI. Comatose and resuscitated			
		I. Externally			II. Lower jaw			III. Upper mouth/throat			IV. Deep esoph						
		Hook & line >.5 cp. len.	Hook & line <.5 cp. len.	All gear re-moved	Hook & line >.5 cp. len.	Hook & line <.5 cp. len.	All gear re-moved	Hook & line >.5 cp. len.	Hook & line <.5 cp. len.	All gear re-moved	Hook & line >.5 cp. len.	Hook & line <.5 cp. len.	releas-ed en-tangled	disen-tangled	Hook & line <.5 cp. len.		All gear re-moved
Leatherback	103	7	20	32	0	0	1	0	1	8	0	0	2	32	0	0	0
Loggerhead	46	0	0	12	0	0	10	0	2	14	0	4	0	4	0	0	0
All species	149	7	20	44	0	0	11	0	3	22	0	4	2	36	0	0	0

Mortality ratio:

Hardshells	0.20	0.10	0.05	0.30	0.20	0.10	0.45	0.35	0.25	0.60	0.50	0.50	0.01	0.70	0.60	1.00
Leatherbacks	0.30	0.15	0.10	0.40	0.30	0.15	0.55	0.45	0.35	0.70	0.60	0.60	0.02	0.80	0.70	1.00

Overall Ratio:		Calculated mortality for each cell in the matrix (no. turtles times mortality ratio)															
Leatherback	0.131	2.1	3	3.2	0	0	0.15	0	0.45	2.8	0	0	1.2	0.64	0	0	0
Hardshell**	0.170	0	0	0.6	0	0	1	0	0.7	3.5	0	2	0	0.04	0	0	0
All species	0.143	2.1	3	3.8	0	0	1.15	0	1.15	6.3	0	2	1.2	0.68	0	0	0

\*Estimates of the ratio of entangled only to total takes were obtained from a subsample of sets where all turtles were caught on 18/0 and 20/0 circle hooks. This ratio was used to estimate entangled only takes from the hooked takes on 18/0 and 20/0 circle hooks from 2002-2003. The ratio of released entangled leatherbacks to total entangled was 0.05 for all hook types in 2002-2003. This ratio was used to estimate the number of released entangled leatherbacks for 18/0 and 20/0 circle hooks. No loggerheads were ever released entangled. All other numbers of turtles by categories are totals from the NED observer data as summarized by Epperly.

\*\*All hardshell turtles assumed to have a mortality ratio like loggerheads, since there were too few NED data on other spp to make direct estimates for olive ridley or green turtles